Comparative Punctate Pressure Sensitivity Assessment Reveals Human Tongue Is More Sensitive Than Fingertip

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Abstract

The tongue is what helps us participate in conversation and enjoy the food we eat. Yet, its sensitivity to tactile stimuli has not been characterized as completely as other systems, such as the fingertip. The purpose of this study was to determine the relative tactile sensitivity of the tongue versus the fingertip to provide insight into the tongue's mechanosensitivity. Due to results from previous studies on roughness and point and edge detection, it was hypothesized that subjects would be better able to discriminate between punctate pressure stimuli with their tongue than their fingertip. Relative tactile sensitivity of the fingertip and the tongue was evaluated in healthy individuals ($n = 30$, 14m/16f, aged 19-28) using the forced-choice, up–down staircase method. In separate conditions, each subject was asked to discriminate between two punctate stimuli ($F = 0.0044$-0.010 g) when presented to their finger or their tongue using a Luneau Cochet-Bonnet Aesthesiometer (Western Ophthalmics Corporation, Lynnwood, WA). The force at the reversals minus the baseline force were averaged for each condition to obtain just noticeable difference (JND) thresholds and compared using a two-tailed, paired t-test ($\alpha = 0.05$). The force needed to evoke a JND was significantly ($p = 0.018$) smaller in the tongue (0.0061 ± 0.0001 g) compared to the fingertip (0.0067 ± 0.0002 g). This agrees with the original hypothesis that people were better able to discriminate between stimuli with their tongues, therefore concluding that the tongue is more sensitive to punctate-pressure than the fingertip. While the reason for the tongue's heightened sensitivity is unknown, it may reflect the closer proximity of mechanoreceptors to the lingual surface or it may indicate a greater density of mechanoreceptors on the tongue as compared to the fingertip allowing for easier discrimination of punctate stimuli. This experiment lays the foundation for other experiments comparing the sensitivity of the fingertip and the tongue, such as roughness and point-and-edge recognition, with the overall goal

of determining the mechanisms behind texture perception associated with the consumption of foods and beverages.

Introduction

The human tongue serves many different purposes, including speaking and eating, and work has been done to characterize the underlying processes and corresponding sensitivities (Hiiemae et. al 2003, Doty et. al 2016). Previous studies have shown that the tongue has high tactile acuity, yet the tongue's sensitivity to tactile stimuli has not been as heavily researched as other highly sensitive systems, such as the fingertip (Miles et. al 2018, Linne et. al 2017, Bangcuyo et. al 2017, Weinstein 1968). Previous studies have also suggested that lingual tactile acuity has been linked to food texture preferences, and therefore understanding the sensitivity of the tongue can be of use to the food and beverage industry (Lukasewycz et. al 2012).

The purpose of this study was to improve upon the methods previously used to determine the relative punctate-pressure sensitivity of the tongue versus the fingertip by using a lower force threshold and Luneau Cochet-Bonnet Aesthesiometers as stimuli (Weinstein 1968, Myles et. al 2007). The Semmes-Weinstein filaments used in previous studies only had a minimum force of 0.008 g, which was not low enough to determine a detection threshold. The Cochet-Bonnet aesthesiometers provide stimulus forces to 0.0044 g and can be adjusted in smaller increments, which is more ideal for threshold detection. Additionally, since the force of the Cochet-Bonnet aesthesiometers is adjusted by simply changing the length, the area of application is held constant, a variable that is not controlled with the Semmes-Weinstein filaments. By determining the punctate-pressure sensitivity of the tongue, the mechanosensitivity of the tongue can be better compared and contrasted to those of the fingertip. The results of this study are intended to complement the findings from the roughness and point-and-edge recognition studies, which when combined provide a more detailed picture of lingual sensitivity and ultimately may help to reveal the mechanisms behind texture perception.

Based on these previous studies, it was hypothesized that subjects would be better able to discriminate between punctate stimuli with their tongue than their fingertip, and therefore have a lower just-noticeable difference (JND) threshold for their tongue than their fingertip.

Objective

The goal of this study was to compare the punctate sensitivities of the fingertip and the tongue in order to gain insight into the mechanisms behind texture perception associated with the consumption of foods and beverages.

Methods

Subject Selection

Subjects (n = 30, 14m/16f, aged 19-28) were recruited from the Ohio State University's Sensory database, excluding individuals who were over the age of 30, had a history of xerostomia, professionals or hobbyists whose work with their hands may lead to fingertip calluses, smokers, those who might be immunocompromised, and those who had visible sores, scars, or other surface deformations on the mouth, tongue, or fingertips. Subjects were enrolled under written informed consent (2013B0277).

Session Methodology

Subjects were instructed not to eat food or drink coffee or tea one hour prior to their testing session. Each session consisted of testing one panelist and took about 30 minutes. Upon arrival subjects were asked which hand they would prefer to use for fingertip sensitivity testing, advising them if they had any cuts or limited wrist mobility to use the other hand. They then were instructed to wash their hands. Upon re-entering the room, they were seated in a dental chair and instructions about the upcoming session were given verbally, informing them that while they are blindfolded they would be discriminating between pairs of stimuli on first either their fingertip or their tongue and then secondly with the other tissue. They were informed that the stimuli were very gentle and if they could not feel the stimulus or the two stimuli felt the same they still had to choose which one felt stronger or more intense, and that they would be reporting their choice verbally. Tactile sensitivity of both the fingertip and the tongue were evaluated using the forced-choice, up–down staircase method. The tissue that was tested on first alternated between following panelists. Stimuli were presented using two Luneau Chochet-Bonnet Aesthesiometers (Luneau Technologies, Prunay-le-Gillon, France, Figure 1). Force could be controlled by adjusting the length of the monofilament. Panelists were blindfolded using a sleep mask for the duration of testing so that evaluation was only influenced by tactile sensitivity.

Figure 1. Luneau Chochet-Bonnet Aesthesiometers. The length of the monofilament was adjusted by sliding along the ruler from 35 (0.010 g) to 60 mm (0.0044 g) and secured with the rubber band. One aesthesiometer was always presented at 60 mm while the other was adjusted according to performance on the forced-choice, up-down staircase method.

Forced-Choice, Up-Down Staircase Method

Each trial consisted of a pair of stimuli whose order of presentation was randomized. Forces for ¼ centimeter and ¾ centimeter monofilament lengths were determined via interpolation from manufactures' data. Stimuli were presented on verbal cues of "one" and "two" so that the subject knew when each stimulus was presented. One stimulus stayed at a constant force of 0.0044 g, but the second filament's length was adjusted by increments of ¼ cm, with corresponding forces ranging from 0.0052 g to 0.010 g, starting in the middle at 0.0071 g. If the incorrect stimulus was chosen as being stronger, the varied force in the next trial would be a step higher than the last (a shorter monofilament), resulting in a larger difference in forces. Conversely, if the correct stimulus was chosen as being stronger, the varied force in the next trial would be a step lower than the last (a longer monofilament), resulting in a smaller difference in forces. Whether the subject identified the stronger stimulus correctly or not was recorded for each trial (Figure 2). When the subject switched from getting one right to getting one wrong or vice-versa, this trial was counted as a reversal. When the eighth reversal occurred, the trials ended for the first tissue and the same procedure was repeated on the second tissue, again beginning at a force of 0.0071 g. Stimuli were presented on the anterior tip of the tongue only, and the fingertip of the index finger on the hand of their choice only.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
5.75cm							✓	✗		✗				✓
5.50cm						✓			✓		✗		✓	
5.25cm			✗		✓							✓		
5.00cm		✓		✓										
4.75cm	✓													
4.50cm														
4.25cm														
4.00cm														
3.75cm														

Figure 2. Example score sheet used on each tissue for each panelist. A check mark indicates the correct answer was given, an X indicates the wrong answer was given, and highlighted answers denote reversals. The force is denoted by length of the monofilament.

Sanitization

In between subjects, the two aesthesiometers were sanitized by submerging the devices in ASP CIDEX OPA (Johnson and Johnson Medical Devices, Irvine, CA) for 12 minutes, then rinsed with water, and then dried with pressurized air.

Data Analysis

Just noticeable difference (JND) thresholds were calculated by taking the average of the difference between the forces of each of the eight reversals, and compared using a two-tailed, paired t-test ($\alpha = 0.05$). Binomial statistics were also run to compare the number of individuals with a lower JND for their tongue and their fingertip. A two-tailed, unpaired t-test ($\alpha = 0.05$) was used to compare the relative JND between subjects better with the finger and people better with the tongue.

Results and Discussion

Just Noticeable Difference

On average, the force needed to evoke a JND was significantly ($p = 0.018$) smaller in the tongue (0.0061 ± 0.0001 g) compared to the fingertip (0.0067 ± 0.0002 g) (Figure 3). Since the tongue had a lower JND, it agrees with the original hypothesis that the tongue would better be able to discriminate between stimuli and is therefore more sensitive than the fingertip. While the reason for the tongue's heightened sensitivity is unknown, it may reflect the closer proximity of mechanoreceptors to the lingual surface compared to the fingertip or may indicate that there is a greater density of mechanoreceptors on the tongue than the fingertip, which allows for easier discrimination of punctate stimuli. It is also notable that the SEM for the fingertip was much larger compared to the tongue, meaning that overall sensitivity of the fingertip varied more than that for the tongue, but on average the finger was less sensitive.

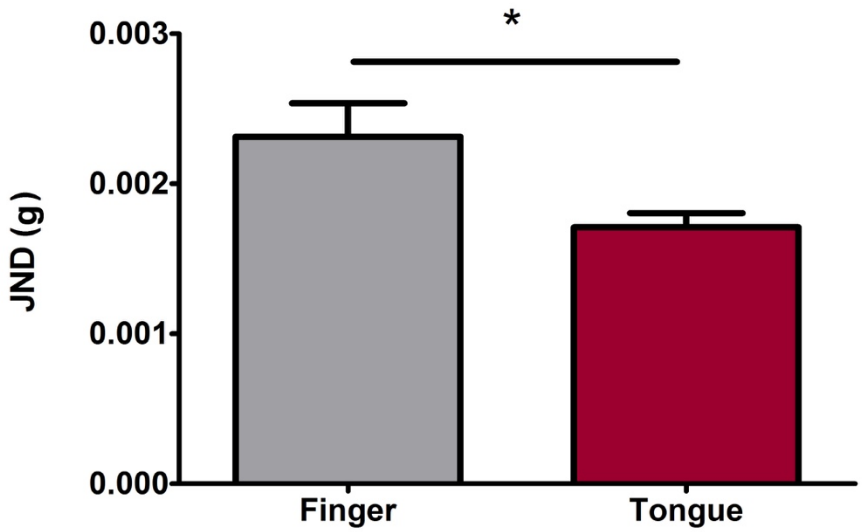

Figure 3. Average punctate pressure JNDs of the fingertip and the tongue. The average JNDs were calculated by taking the average of the difference between the force of each reversal and the baseline force (0.0044 g) for each tissue. The average JND was significantly lower for the tongue than for the fingertip ($p = 0.018$). Error bars represent SEM.

Relative Acuity

Subjects who were better with their fingers also had significantly closer JNDs for their fingers and tongues than individuals that were better with their tongues ($p = 0.0025$), Figure 4. This suggests that subjects that had a smaller JND for their fingertip were only marginally better with their finger and generally had close equal acuity with both systems, while subjects who were better with their tongues were much better able to discriminate with their tongues than their fingertips. This suggests a large variability in sensitivity for the fingertip while across the board subjects had high acuity with their tongue. This matches what was interpreted from Figure 3 with the larger SEM for the fingertip than the tongue.

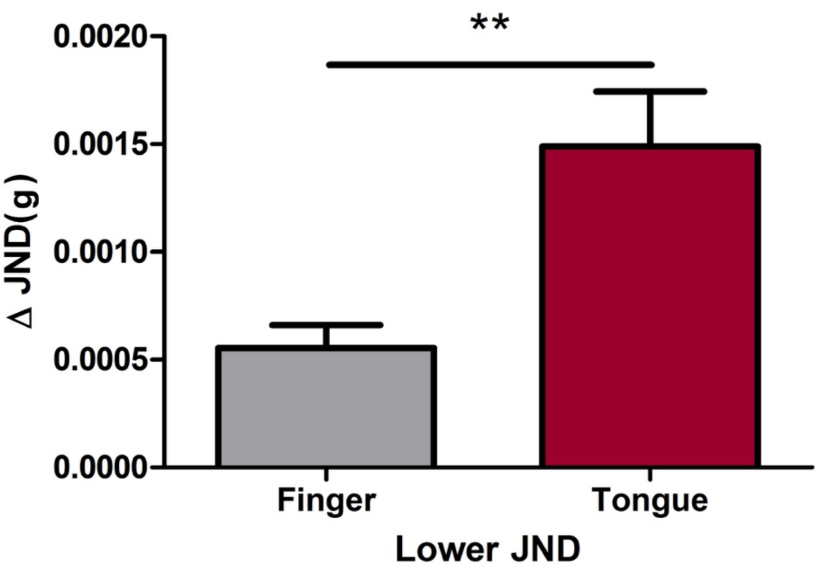

Figure 4. Relative punctate pressure sensitivity of the fingertip and the tongue. Relative sensitivity was calculated as the absolute value of the difference in JNDs for the fingertip and the tongue of each subject and averaged for two groups, those who had a lower JND for the finger ($n = 13$) and those who had a lower JND for the tongue ($n = 17$). Subjects that had a lower JND with their tongue had a significantly greater difference in JNDs between their tongue and their fingertip than those who had a lower JND with their finger ($p = 0.003$). Error bars represent SEM.

Conclusions

Subjects were better able to discriminate between punctate-pressure stimuli with their tongues, which aligns with the original hypothesis that the tongue is more sensitive to punctate stimuli. The tongue's heightened sensitivity may reflect the closer proximity of mechanoreceptors to the lingual surface or more densely populated mechanoreceptors on the tongue as compared to the fingertip. Subjects that had lower JNDs with their tongues were significantly more sensitive with their tongues than their fingertips, suggesting the fingertip has more variation in its sensitivity. A possible evolutionary reason for the conservation of lingual sensitivity as compared to fingertip sensitivity is that the oral cavity is the last line of defense before ingestion of a hazard. Additionally, the oral cavity is informed exclusively by touch while the fingertips have additional input from visual cues. Potential future studies include analysis of other textural cues, determining the implications that heightened sensitivity may have on behavior, and ultimately understanding how texture perception influences liking of food and beverages and intent to purchase.

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